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AN IMPROVED DC POWER REGULATOR*

234600

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Introduction

Temperature control of a spontaneously cooling object by means of regulated electric heating may be achieved with a low-level, dc amplifier of thermocouple or bridge signals [1,2] together with a dc power-regulating amplifier [3–6]. The use of dc heating current avoids ac pickup by low-level circuits in the cryostat. Although dc amplifier circuitry is well known [7-10] the modification of direct-coupled circuits, for purposes other than the original design, may be surprisingly difficult.

Stability Requirements

Whereas the performance of a high-gain control loop is nearly independent of gain and the power regulator is merely an element of the temperature-control loop, the exceptionally wide range of conditions encountered in cryostats and calorimetry often presents problems of poor effective control, especially when the spontaneous cooling diminishes toward zero. Dependence of controlled temperature upon amplifier drifts, for the described system in the absence of internal heat sources, follows readily with defined symbols. Power regulator output emf and cryostat heat flow are [11], respectively,

$$V = V_0 - AS(T - T_1) \quad , \tag{1}$$

$$V^2/rR = k(T - T_0) \quad , \tag{2}$$

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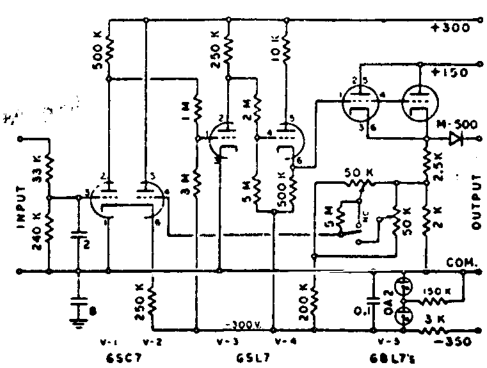

Fig. 1. DC power regulator.

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from which, at the balance point $T = T_1$,

$$(\partial T/\partial V_0) = [AS + krR/2V_0]^{-1} . \tag{3}$$

Power Regulator Characteristics

The circuit of Fig. 1 is characterized as follows:

1. Common input and output circuits are useful with grounded amplifiers [1].
2. The high-current output power supply need not be regulated.
3. The no-signal output is manually adjustable to over 50 v for steady state.
4. Output noise is under 0.05 v at low output values.
5. Input signals (plus or minus) are amplified twofold and added algebraically to the set output.
6. Response is approximately linear, important at low output.
7. Input up to 50 v is limited only by output loading.
8. The input impedance is high; observed output impedance is 10 ohms.
9. Tube heater failures will decrease or cut off the output.
10. The output booster relay circuit, useful for step heating in calorimetry, does not alter the low output impedance.

Circuit Details

Characteristics (2), (4), (6), and (8) result from negative feedback to V-1 via cathode-coupled V-2 from an amplifier gain of approximately 1000. Drift of the output should be sought in sources affecting bias requirements of V-1 and V-2, such as plate supply emf, load resistors, and tube aging, as well as in elements of the feedback circuit. These include the B-minus supply, the 200-kilohm commercial manganin resistor governing current in the 10-turn helical potentiometers, and the 10-w wire-wound output dividers.

A small but annoying negative output can arise from potentiometer current flowing in the output divider if V-5 is shut off. This has been reduced by increasing the output divider resistances to obtain compensating V-5 current when the potentiometer setting is zero. The M-500 silicon diode provides latitude for drifts.

The observed effect of B-plus emf variation upon 9 to 11 v output on a 250-ohm load was linear, $d(\text{out emf})/d(\text{B + emf}) = 0.042$.

Approximately 10% change of signal gain occurs with full-scale change of the potentiometer and steady-output setting.

Output Characteristics

By means of an adjustable-zero, adjustable-range potentiometer recorder, an initial output of 11.00 v on a 250-ohm load was observed to increase to 11.06 v in 0.5 hr, whereafter up to 7 hr it was 11.10 ± 0.04 v. At a lower level, it was found to be 0.50 ± 0.02 v during 4 hr, increasing during the next 18 hr to 0.56 ± 0.02 v.

Heater load resistance should be low to obtain high power change from a given signal. Detailed examination of characteristics for two parallel 6BL7 tubes in the circuit in Fig. 1 shows, however, that maximum absolute power of about 7 w may be generated in a load resistance of 300 to 500 ohms. Substitution of two 6AS7-G tubes at V-5 affords 25 w maximum in 100-ohm load. For these tubes, plate emf must be 100 v. Zero output, however, demands increased bias obtained by increasing the resistor between V-3 plate and V-4 grid to 3 megohms or more.

Nomenclature

A = combined emf gain of amplifiers

k = thermal conductance between T and T_0

$r \equiv (1 + R_0/R)^2$

R_0 = power regulator output circuit impedance

R = heater load resistance

S = thermometer sensitivity, emf/deg

T_0 = heat-sink temperature

T = controlled temperature

T_1 = controller set-point temperature, steady state

V = power regulator output emf

V_0 = output emf at steady rate, $T = T_1$.

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